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Imaging of cartilage repair procedures

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Abstract

The rationale for cartilage repair is to prevent precocious osteoarthritis in untreated focal cartilage injuries in the young and middle-aged population. The gamut of surgical techniques, normal postoperative radiological appearances, and possible complications have been described. An objective method of recording the quality of repair tissue is with the magnetic resonance observation of cartilage repair tissue (MOCART) score. This scoring system evaluates nine parameters that include the extent of defect filling, border zone integration, signal intensity, quality of structure and surface, subchondral bone, subchondral lamina, and records presence or absence of synovitis and adhesions. The five common techniques of cartilage repair currently offered include bone marrow stimulation (microfracture or drilling), mosaicplasty, synthetic resorbable scaffold grafts, osteochondral allograft transplants, and autologous chondrocyte implantation (ACI). Complications of cartilage repair procedures that may be demonstrated on magnetic resonance imaging (MRI) include plug loosening, graft protuberance, graft depression, and collapse in mosaicplasty, graft hypertrophy in ACI, and immune response leading to graft rejection, which is more common with synthetic grafts and cadaveric allografts.

Key words: Cartilage; repair; magnetic resonance imaging

Introduction

Focal cartilage injuries in the young and middle-aged population can lead to premature osteoarthritis if untreated. A variety of cartilage repair procedures are currently offered to patients with traumatic cartilage injuries. In this context, it is necessary for radiologists to be aware of the spectrum of surgical techniques, normal imaging appearances, and possible complications that may be apparent on imaging. Magnetic resonance imaging (MRI) remains the mainstay of imaging after cartilage repair; however, conventional radiographs and computed tomography (CT) are also used in select situations. Imaging is often performed for baseline documentation and prognostication when the postoperative course is uneventful. MRI may be used to monitor progressive stages of graft healing including revascularization, resorption, incorporation, and remodeling. More often, MRI is requested in cases with persistent, recurrent, or new symptoms after surgery.

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MRI Assessment

An objective method of recording the quality of repair tissue is with the magnetic resonance observation of cartilage repair tissue (MOCART) score [Table 1].[1,2] This scoring system assesses nine parameters. In addition to the structural imaging of articular cartilage, a number of pulse sequences have been developed to assess the biochemical quality of the reparative tissue; these include T2 mapping for collagen content,[3] T1mapping/delayed gadolinium-enhanced MRI of cartilage (dGEMRIC)[4] for glycosaminoglycan content, and diffusion mapping.[5] T2 cartilage imaging is based on the principle that damaged cartilage has higher T2 values and loss of zonal variation, as compared to normal. In some studies, T2 mapping has been used to assess the efficacy of cartilage repair, with successful repair heralded by T2 values and zonal variation akin to normal cartilage.

Techniques of Cartilage Repair

The five common techniques of cartilage repair currently offered include bone marrow stimulation (microfracture or drilling), mosaicplasty, synthetic resorbable scaffold grafts, osteochondral allograft transplants, and autologous chondrocyte implantation (ACI).[6]

Bone Marrow Stimulation/microfracture Technique [Figures 1 and 2]

It involves using an awl or a pick to create holes at the site of the chondral defect. The purpose of the surgery is to expose the subchondral pluripotential marrow stem cells to form fibrocartilaginous repair tissue. The drilling allows formation of a fibrin clot which acts as a scaffold for reparative tissue formation.

Mosaicplasty or Osteochondral Autograft Transplantation Surgery (OATS)

This entails harvesting osteochondral plugs from a non–weight-bearing area and transplanting at the site of the cartilage defect in the weight-bearing segment [Figures 3 and 4]. The aim of surgery is to have osteochondral plugs perpendicular to the articular surface and congruent with the adjacent normal cartilage. As compared to the microfracture technique, where the repair tissue is fibrocartilage, OATS involves transplantation of the patient's own hyaline cartilage. As compared to cadaveric allografts, osteochondral autografts are less likely to induce immune-mediated graft rejection and rate of graft incorporation is higher.[7] Limitations of this technique are possible donor site morbidities.

Table 1: Cartilage repair tissue assessment: Grading and point scale

Variable	Classes	Points
Degree of defect repair and defect filling	Complete	20
	Hypertrophy	15
	Incomplete >50%	10
	<50%	5
	Subchondral bone exposed	0
Integration to border zone	Complete	15
	Incomplete	10
	Demarcating border seen	5
	Defect visible	0
	<50% length of repair tissue	
	>50% length of repair tissue	
Surface of the repair tissue	Intact	10
	Damaged	5
	<50% length of repair tissue	0
	>50% length of repair tissue	
Structure of the repair tissue	Homogenous	5
	Inhomgenous	0
Signal intensity of the repair tissue	DualFSE	
	Isointense	15
	Moderately hyperintense	5
	Markedly hyperintense	0
	3D gradient	15
	Isointense	5
	Moderately hypointense	0
	Markedly hypointense	
Subchondral lamina	Intact	5
	Not Intact	0
Subchondral bone	Intact	5
	Not intact	0
Adhesions	No	5
	Yes	0
Effusion	No	5
	Yes	0

MOCART: Magnetic resonance observation of cartilage repair tissue, FSE: Fast spin echo

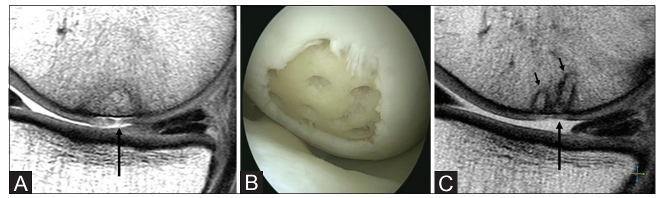

Figure 1 (A-C): Microfracture technique, MOCART score 70. (A) Sagittal PD image shows full-thickness osteochondral injury following trauma. (B) Intraoperative image shows small holes in the subchondral bone created by a pick introduced through arthroscopic portal. The procedure is performed to promote multipotential bone marrow stem cells to form fibrocartilage. (C) Postoperative follow-up MRI shows formation of new repair tissue (long arrow). The repair tissue is congruent with native cartilage. Tracts of microfractures in subchondral bone (small arrows)

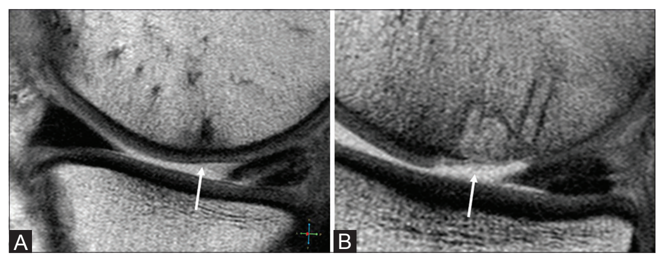

Figure 2 (A, B): Microfracture technique in two different patients. (A) Follow-up MRI shows adequate fill of the cartilage defect by reparative tissue which is normal in signal and congruent with the adjacent native cartilage; MOCART score is 95. (B) Follow-up MRI in a different patient shows incomplete filling of the defect and exposure of subchondral bone; MOCART score is 30

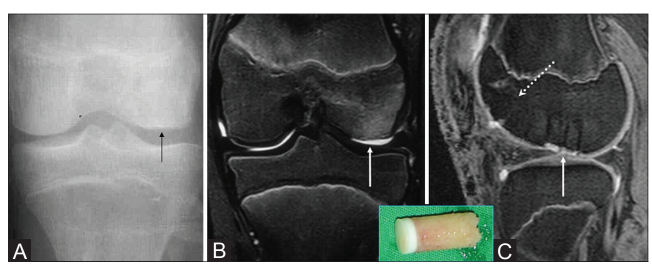

Figure 3 (A-C): Mosaicplasty after bike accident in a 13-year-old boy. (A) Radiograph shows flattening of the lateral femoral condyle (arrow). (B) Coronal Short Tau Inversion Recovery (STIR) MRI shows osteochondral lesion (arrow). (C) Osteochondral plugs (inset) were harvested from non–weight-bearing surface (dotted arrow) and transplanted at site of defect (solid arrow) at weight-bearing articulating surface. Postoperative sagittal Proton Density (PD) image shows excellent congruity of repair tissue (solid arrow) with parent cartilage. The repair tissue shows normal thickness, signal and smooth surface

Synthetic Grafts

These involve using artificial osteochondral scaffolds to replace the focal defects of bone and cartilage [Figures 5 and 6]. The technique is similar to mosaicplasty, except that there is no need for graft harvest. The advantage of this technique is the absence of donor site morbidity associated with OATS. The disadvantage of the present generation of artificial scaffolds is the risk of immune reactions, early graft resorption with collapse, and incomplete graft resorption.[8]

Osteochondral Allograft Transplantation

This involves the transplantation of osteochondral grafts harvested from a cadaver into the cartilage defect via an arthrotomy. This technique is indicated in large or sectoral osteochondral defects. The harvested osteochondral allograft is matched with the size and contour of the chondral defect [Figures 7 and 8]. The advantage in this technique is that the cartilage is hyaline cartilage and not just reparative fibrocartilage. Moreover, this is the only technique available to reconstruct the exact three-dimensional topography of large sectoral articular defects. However, the availability of fresh cadaveric specimens with adequate cartilage thickness remains a challenge. Other risks include transmission of disease to the recipient from the donor and immune-mediated rejection of the transplant.

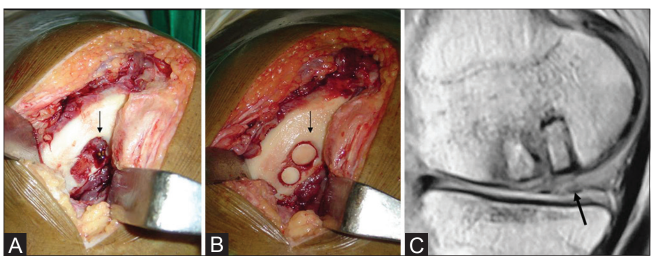

Figure 4 (A-C): Mosaicplasty with poor MOCART score of 55. (A) Intraoperative image shows large osteochondral lesion (arrow) of medial femoral condyle. (B) Osteochondral plugs (arrow) have been placed in the lesion. (C) Postoperative sagittal T2W MRI shows graft subsidence (arrow) and poor congruity with the adjacent parent cartilage

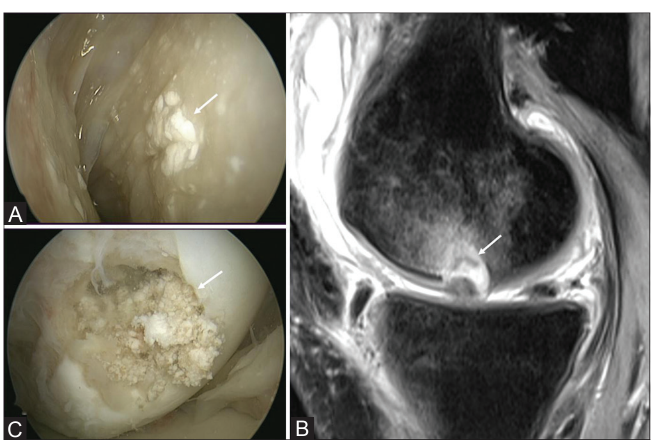

Figure 6 (A-C): Failure of synthetic osteochondral scaffold implant with a MOCART score of 10. (A) Follow-up arthroscopic image show foreign body reaction with synovitis and (B) failure of graft incorporation (arrow). (C) Follow-up sagittal proton density MRI shows failure of graft incorporation with incomplete integration, damaged surface, and inhomogeneous signal of graft

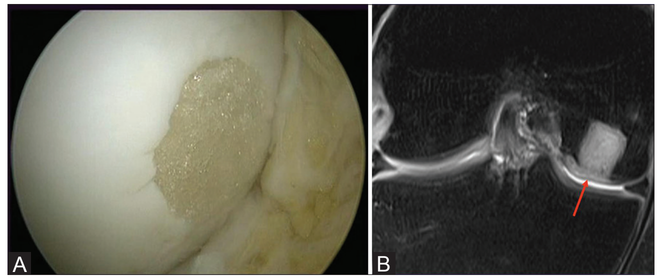

Figure 5 (A, B): Synthetic osteochondral scaffold. (A) Arthroscopic image. (B) Coronal STIR MRI shows adequate incorporation of synthetic graft with a MOCART score of 90

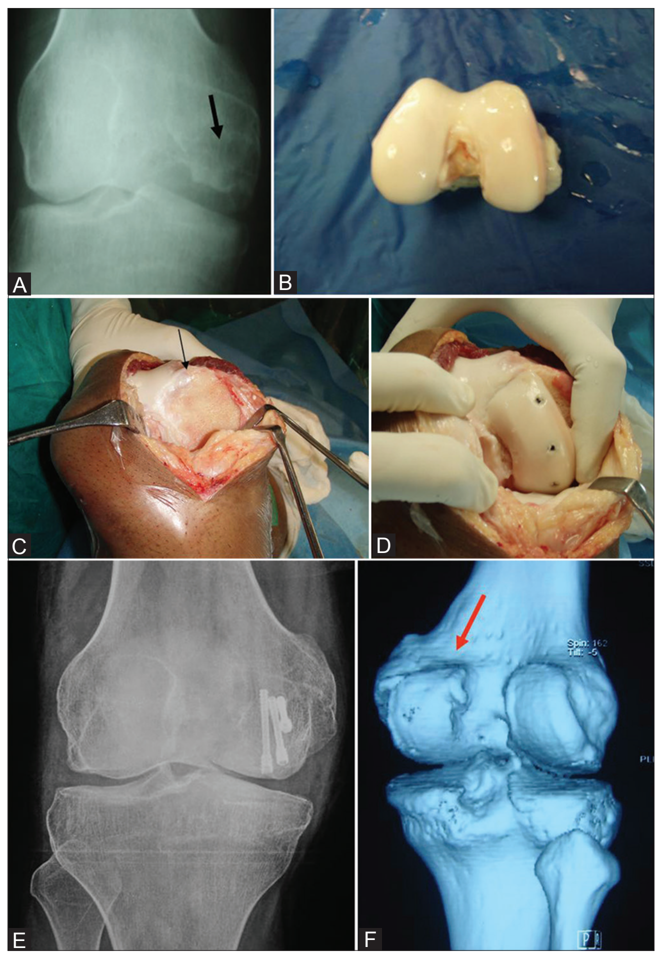

Figure 7 (A-F): Osteochondral allograft transplantation. (A) Radiograph shows medial femoral condyle avascular necrosis with collapse, flattening, and deformation. (B) Photo of cadaveric allograft. (C) Arthrotomy to expose the articular defect before transplantation. (D) A size- and shape-matched sectoral osteochondral allograft has been transplanted. (E and F) Follow-up postoperative radiograph and 3D CT shows graft union and topographic restoration

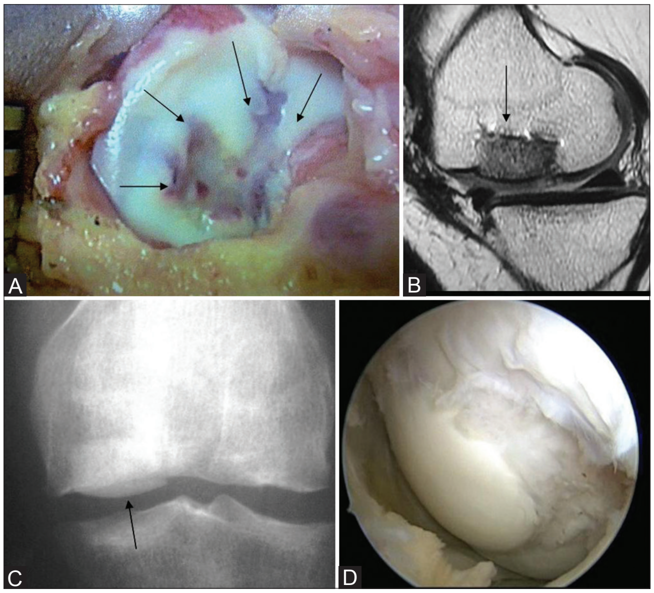

Figure 8 (A-D): Massive medial femoral condyle osteochondral lesion treated with osteochondral allograft and has a postoperative MOCART score of 95. (A) Intraoperative image shows large osteochondral defect (arrows) of medial femoral condyle. (B) Postoperative MRI and (C) frontal radiograph show adequate incorporation of the graft (arrows) and a MOCART score of 95. (D) Second look arthroscopic image demonstrating allograft incorporation and normal articular cartilage topography

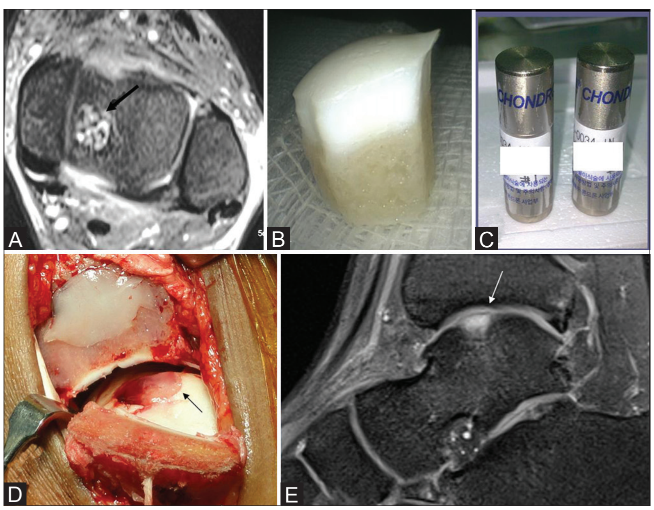

Figure 10 (A-E): ACI for talar osteochondral lesion (A). In stage 1 of the procedure, cartilage biopsy specimen (B) was obtained from a remote area and chondrocytes were harvested in vitro (C). In stage 2 of the procedure, the harvested chondrocytes were implanted (arrow in D). Postoperative 3-month follow-up MRI shows adequate integration of the graft (arrow in E)

ACI Technique

In this two-stage technique, in the first stage, a cartilage biopsy is obtained from a non–weight-bearing segment and the chondrocytes are cultured for 3-6 weeks *in vitro*.[9] In the second stage of the procedure, the cultured chondrocytes are implanted via an arthrotomy into the cartilage defect [Figures 9-11]. The current generation of fibrin-ACI uses an injectable delivery system, whereas earlier ACI techniques required periosteal flaps and collagen matrix for cell delivery.

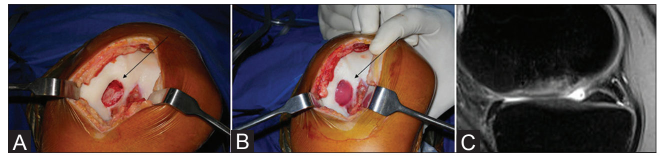

Figure 9: Autologous chondrocyte implantation with a MOCART score of 95. (A) Arthrotomy performed to expose focal chondral defect on medial femoral condyle prior to autologous chondrocyte implantation. (B) The chondral defect has been debrided, and chondrocytes have been injected using a fibrin-glue delivery system. (C) Follow-up sagittal proton density MR image shows defect repair with complete filling, adequate integration to border zone, intact surface of repair tissue with fairly homogenous signal, and a MOCART score of 95

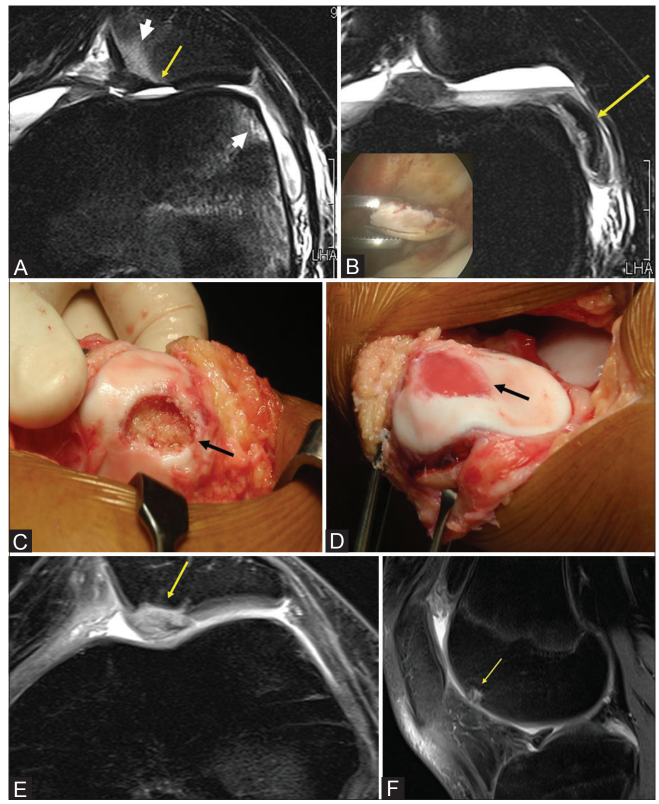

Figure 11 (A-F): Patellofemoral dislocation treated with ACI; MOCART 85. (A) MRI shows patellar osteochondral lesion (arrow) and bone contusions (arrowheads). (B) Corresponding loose osteochondral fragment. Inset shows arthroscopic fragment removal; cartilage biopsy for harvesting chondrocytes was performed at same setting from non-weight-bearing lateral femoral condyle (stage 1 surgery). (C) Open ACI 6 weeks later (stage 2), intraoperative image shows debrided defect (D). Post ACI image shows grafted chondrocytes filling defect. (E) Post ACI MRI shows hypertrophied repair tissue. (F) Cartilage harvest site

Complications of Cartilage Repair Procedure

Complications of cartilage repair procedures that may be demonstrated on MRI include plug loosening, graft protuberance [Figures 4 and 11], graft depression, and collapse in mosaicplasty. ACI can be complicated by graft hypertrophy [Figure 11][10-12] within 6 months after the procedure. The harvest site is also evaluated for surface incongruity. Immune response leading to graft rejection is a complication [Figure 6] encountered more commonly with synthetic grafts and cadaveric allografts. In case of allografts, CT and conventional radiographs are used to assess topographical restoration [Figure 7], progressive stages of allograft union and healing [Figure 8], status of overlying articular margin, and can demonstrate allograft collapse in failed cases.

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